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INSTRUMENTED ANTIFRICTION BEARING AND ELECTRICAL MOTOR EQUIPPED THEREWITH

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Instrumented antifriction bearing and electrical motor equipped therewith

The invention relates to an antifriction bearing in which a rotating member of the bearing supports an encoder and a nonrotating member of the bearing supports a sensor for the purpose of determining certain rotation parameters such as the speed or the angular position of the rotating element supporting the encoder.

Such devices find their application in many fields, such as electric motors in which they are required to operate in severe conditions of speed and temperature.

Through document FR-A-2 754 903, an antifriction bearing is known comprising a sensor integral with the nonrotating race, of the Hall effect probe type, and an encoder integral with the rotating race moving in rotation with a slight air gap relative to the sensor while being capable of producing in the sensor a periodic signal with a frequency proportional to the speed of rotation of the rotating race.

The encoder comprises an annular active portion made with a plastic magnet and provided with an active zone placed opposite the sensor, supplemented by a reinforcement portion consisting of two annular elements placed in contact with the active portion, either side of the active zone. Such an antifriction bearing is usually satisfactory, particularly in the field of electric motors. However, this type of encoder cannot operate at high temperatures, above 120°. The sensor and the encoder do not operate satisfactorily if they are subjected to high intensity external magnetic fields, for example the magnetic fields induced by the coils of the stator of electric motors and/or by the

electromagnetic brake built into said motors. Finally, the axial compactness of the antifriction bearing thus instrumented is not optimal and does not make it easy to incorporate.

In high power asynchronous electric motors, the control of the motor requires the rotation parameters of the motor to be detected. Specifically there is a need to know the speed and direction of rotation of the rotor to be able to adapt the frequency, the current and the direction of the current entering the coils of the stator. The use of a multipolar type encoder associated with a Hall effect probe is suitable only for applications in which the power and the control requirements are relatively imprecise, for example for a fan motor that operates at constant speed during use.

Also known are the optical type sensor encoder systems, for example industrial encoders, which are not likely to be built into a motor, which require a mechanical interface for driving by the electric motor and which are relatively sensitive to impacts and to temperature.

The invention aims to remedy these disadvantages.

The invention proposes an instrumented antifriction bearing that is axially very compact, capable of operating at high temperatures while delivering precise detection, including when they are subjected to intense magnetic fields.

The instrumented antifriction bearing device, according to one aspect of the invention, comprises a rotating portion, a nonrotating portion and an assembly for detecting rotation parameters comprising an encoder and a sensor integral with the nonrotating portion and provided with a sensor unit. The sensor comprises at

least one microcoil with substantially flat winding, placed on a support of a circuit mounted in the sensor unit of the nonrotating portion such that said microcoil comes axially opposite the encoder. This provides satisfactory axial compactness.

In one embodiment, the device comprises a plurality of substantially radial coplanar reception microcoils. The sensor may thus achieve precise detection.

In another embodiment of the invention, the device comprises a plurality of reception microcoils placed on a plurality of parallel radial planes. This provides a greater number of reception coils providing enhanced precision.

Advantageously, the device comprises a transmission coil placed in the sensor unit. The transmission coil may also be a microcoil, preferably with flat winding.

Preferably, the device comprises at least one transmission coil, at least one reception coil and a data processing circuit placed on the support. These elements can be used to retain a satisfactory axial compactness. The coils may be made in printed circuit technology. The support may be a printed circuit substrate in the form of a resin circuit board. In other words, the sensor comprises active and/or passive elements combined in a single module integral with the nonrotating portion.

Advantageously, the device comprises a plurality of microcoils linked together in pairs and angularly offset in order to generate a differential signal. The encoder may comprise an encoder wheel whose active zone is made of an electrically conducting metal.

Advantageously, the encoder comprises a printed circuit whose substrate is annular in shape and is provided with metallized sectors and nonmetallized sectors. The printed circuit may be mounted on a nonrotating race of the antifriction bearing.

In another embodiment of the invention, the encoder comprises an encoder wheel with windows or with teeth attached to a rotating race of the antifriction bearing. The encoder may be made as a solid block. The encoder may be made of pressed sheet metal. Such an encoder is capable of operating at high temperatures. Windows are here intended to mean holes formed in the encoder between two circumferentially continuous portions. Teeth are intended to mean portions of material that are integral with a circumferentially continuous portion of the encoder. The encoder may comprise an axial portion fitted onto a cylindrical bearing surface of the rotating race and a radial portion directed towards the other race and in which the windows or the teeth are formed.

For reasons of compactness, it is advisable to ensure that at least one portion of the encoder is placed in the space situated between the antifriction bearing races, that is to say radially between the cylindrical surfaces of the races which extend between the bearing raceways and the frontal surfaces delimiting said races, and axially at right angles to said cylindrical surfaces, between the rolling elements and the frontal radial surfaces of the antifriction bearing races.

In another embodiment of the invention, the encoder is placed outside the space situated between the antifriction bearing races.

In one embodiment of the invention, the sensor unit is

annular.

In another embodiment of the invention, the sensor unit occupies an angular sector of less than 360°, for example of the order of 120°.

In one embodiment of the invention, the data processing circuit is an application-specific integrated circuit (ASIC).

The invention also proposes an electric motor comprising a rotor, a stator, at least one antifriction bearing supporting the rotor, and a sensor assembly comprising an encoder and a sensor. The sensor comprises at least one microcoil with substantially flat winding placed on a support of a circuit mounted in the sensor unit integral with the stator such that the microcoil comes axially opposite the encoder. Usually, the winding will comprise an outer race integral with the stator and supporting the sensor unit and an inner rotating race integral with the rotor and supporting the encoder. The motor may be of the high power asynchronous type in which precise control is required by measuring the rotation parameters precisely.

Microcoil here is intended to mean a coil with winding formed on a circuit, for example a copper coil on a printed circuit substrate. The thickness of the card and of the microcoil is of the order of 1 mm.

The invention will be better understood on studying the detailed description of some embodiments taken as nonlimiting examples and illustrated by the appended drawings, in which:

- figure 1 is a view in axial section of an instrumented antifriction bearing, according to one

embodiment of the invention;

- figure 2 is a partial view of the sensor of figure 1;
- figure 3 is a front view in elevation of the encoder of figure 1;
- figure 4 is a front view in elevation of an encoder variant;
- figure 5 is a view in axial section of an instrumented antifriction bearing, according to another embodiment of the invention;
- figure 6 is a front view in elevation of the encoder of figure 5; and
- figure 7 is a wiring diagram of the sensor.

As illustrated in figure 1, the rolling bearing 1 comprises an outer race 2, an inner race 3, a row of rolling elements 4, here balls, placed between the outer race 2 and the inner race 3 and retained by a cage 5, a seal 6 on one of its sides, and on the opposite side a speed sensor 5 integral with the outer race 2 and an encoder 8 integral with the inner race 3.

In the embodiment shown, the outer race is nonrotating and the inner race is rotating. However, the inverse disposition is perfectly conceivable.

The sensor 7 comprises a detection portion 9 illustrated in greater detail in figure 2, a support unit 10 in synthetic material, and a metal element 11 fitted onto a bearing surface of the outer race 2, here in the groove usually used for attaching the seal provided in noninstrumented antifriction bearings. A cable 12 connected to the detection portion 9 is used to transmit information of speed, of position or more generally of the rotation parameters to other units that are capable of exploiting such data and have not been shown.

The encoder 8, see figures 1 and 3, comprises a support portion 13 and an operational portion 14. The support portion 13 is of tubular shape fitted onto a cylindrical bearing surface 3a of the inner race 3 formed between the raceway 3b which is in contact with the rolling elements 4 and a radial surface 3c which forms the end of the inner race 3 in the axial direction on the side of the sensor.

The operational portion 14 is radial and has a plurality of windows 15, of rectangular shape, elongated radially and at the large diameter end of the operational portion 14 allowing a continuous circular portion 16 to remain. The operational portion 14 and the support portion 13 are made in a solid unit, providing an economic and particularly robust construction. The encoder 8 may be made from a metal sheet by means of pressing and punching steps.

It is noticeable that the operational portion 14 is slightly recessed relative to the radial surface 3c of the inner race 3. The encoder 8 is therefore particularly compact and is placed in the space defined radially between the races 2 and 3 of the rolling bearing and axially between the rolling elements 4 and the radial plane through which the end surfaces 2c, 3c of said races 2 and 3 pass.

The detection portion 9 of the sensor 7 comprises a support 17 on which are mounted an integrated circuit 18, for example of the ASIC type, which is intended for the data processing, a transmission microcoil 19 also called an excitation coil and four reception microcoils 20. The circuit also comprises a certain number of filtering elements such as capacitors, resistors, etc., not shown. The detection portion 9 is placed axially at a slight distance from the operational portion 14 of

the encoder 8 and occupies an angular sector of the order of 120°, while being inserted into the support unit 10 which for its part is circular. If necessary, a continuous angular sector of 360° could be provided. The detection portion 9 has a face not covered by the material of the support unit 10 and oriented facing the encoder 8.

The microcoils 19 and 20 are of the flat winding type and may be of the printed circuit kind or even of the integrated circuit kind. The flatness of the windings provides the sensor 7 with excellent axial compactness. In addition, the reception coils 20 have a square outer contour and are placed one after the other on the arc of a circle formed by the support 17, while the transmission coil 19 surrounds the reception coils 20 and is shaped like an arc of a circle. The coils 19 and 20 are connected to the data processing circuit 18, itself connected to the cable 12 in a manner not shown.

The metal element 11 comprises a portion forming a hook 11a bent into the groove of the outer race 2 usually used for fastening a sealing element which, in a noninstrumented antifriction bearing, is conventionally symmetrical with the seal 6.

The metal element 11 is supplemented by a short radial portion directed outward from the portion 11a and in contact on one side with the end radial surface 2c of the outer race 2 and on the other side with the support unit 10 of the sensor 7, and by an axial portion 11c extending from the free end of the radial portion 11b which radially surrounds the support unit 10, with the exception of the cable outlet zone 12 where provision is made for the support unit 10 to extend outward forming a protuberance 21 surrounding the cable 12 and protecting its outlet.

The support unit 10 is made of synthetic material and has a generally annular shape with the protuberance 21 projecting over its periphery and an axial hollow from its radial face on the side of the antifriction bearing that constitutes a housing for the detection portion 9 while covering it on its face opposite the rolling bearing and over its thickness in the radial direction. The support unit 10 and the detection portion 9 are integral. As a variant, the support unit 10 could be metallic.

Figure 4 illustrates an encoder variant in which the support portion 13 is identical to that of the preceding embodiment and the operational portion 14 oriented radially outward from the support portion 13 is formed by a plurality of teeth 22, of generally rectangular shape, elongated radially, whose periphery is circular and which leave between them crenellations 23 of slightly trapezoidal shape.

The mode of operation of the sensor-encoder assembly is similar in both embodiments.

The reception coils 20 are electrically excited by the transmission coil 19 connected to an oscillating circuit.

The transmission coil 19 generates by induction an electric signal in the reception coils 20.

During the rotation of the encoder 8, the windows and the full portions of the operational portion 14 passing before the microcoils produces a variation of the metal mass situated in front of each reception microcoil 20.

In said reception coils 20, this results in a variation

of the phase of the electric signal induced due to losses by eddy currents.

These variations of the electric signal emitted by the various reception coils 20 and processed by the circuit 18 are the basis of the generation of signals representative of the parameters of rotation of the encoder 8 such as the speed of rotation.

The sensor with microcoils allows the instrumented antifriction bearing to deliver reliable information, including when magnetic fields of high intensity are present.

The encoder may be made of an electrically conducting and magnetic metal material, such as steel, or yet electrically conducting and nonmagnetic material, such as aluminum or copper.

The reception microcoils 20 operate in pairs to deliver a differential signal. The reception microcoils 20 of a pair are angularly offset by an angle represented by β and the angular pitch of the windows is represented by ϕ. For the signal be out of phase requires that one of these angles should not be a multiple of the other. This therefore gives $\beta \neq a*\phi$ where a is any integer, the angle β usually being greater than ϕ. For example this could be $\beta = (a+0.5)*\phi$ or $\beta = (a+0.25)*\phi$.

When the encoder passes in rotation before the sensor, the discontinuities of material of the operational portion 14 cause periodic variations of the metal mass that is opposite the reception microcoils 20. If there is metal material before each of the coils of a pair of reception coils, the phase difference between the two differential coils is zero. If there is metal material before at least one of the two reception coils forming

a pair and the metal material is distributed differently before each coil, the losses due to the eddy currents in the metal material will generate a phase difference of the currents. This phase difference may then be processed and extracted adequately by the processing circuit 18, in order to obtain the desired information, such as the angular speed, the direction of rotation, the position, etc.

The generation of the electronic signal does not therefore depend on the level or the direction of a magnetic field sensed by the microcoils, but on the modification of the currents induced by the excitation coil 19 in the reception coils 20 in the presence of the variations of the electrically conducting metal masses passing before said microcoils. The signal is therefore very insensitive to external magnetic fields, which makes the device according to the invention extremely suitable for operating in an environment subjected to strong magnetic fields such as electric motors. The reception coils 20 are distributed on the support 17 with a radial position and angular pitch suitable for cooperating with the operational portion 14 of the encoder 8 and delivering the required signals. If necessary, the number of reception coils 20 may be increased in the circumferential direction or stacking of several coils in the axial direction may be used in order to obtain higher powered signals.

Since the microcoils are extremely thin, as is the processing circuit 18, the sensor 7 has extremely small axial dimensions, allowing integration into a sensor unit 10 itself having very small axial dimensions. Likewise, the encoder may, due to its structure, be axially extremely thin and be easily integrated into the space lying between the bearing races, such that said encoder does not affect the external dimensions of

the instrumented antifriction bearing.

Figures 5 and 6 show a variant with an encoder 8 made with the printed circuit technique. From a conventional printed circuit substrate coated with a thin metal layer, copper for example, a disk is made comprising an alternation of metallized sectors 8a and of nonmetallized sectors 8b. The substrate is electrically nonconducting and the metallized sectors 8a are electrically conducting.

This disk is attached by appropriate means (fitment and/or bonding) onto an axial portion 3d made for this purpose on the rotating race 3 of the bearing 1. This type of encoder wheel has little inertia, great axial compactness and the contours of the active portions may be made with great precision. The aggregate signal is therefore particularly weak.

Figure 7 illustrates in greater detail the electrical functions of the system. It shows that the reception coils 20 are grouped in two pairs numbered 24 and 25 and framed by dashed lines. For clarity of the drawing, the pairs of reception coils 24 and 25 are shown outside the exciting transmission coil whereas in reality they are inside said transmission coil 19.

The coils 19 and 20 are connected to the processing circuit 18. The processing circuit 18 comprises an oscillator 26 whose output is connected to the transmission coil 19, and two phase demodulators 27 and 28 connected to the output of each of the reception coils 20. The circuit 18 also comprises two interpolating comparators 29, 30, mounted respectively at the output of the phase demodulators 27 and 28. At the output, the processing circuit 18 transmits a digital signal representative of at least one parameter

of rotation of the antifriction bearing, such as the speed, the position, the direction of rotation, the acceleration, etc.

This is the method of producing an instrumented antifriction bearing that can be easily integrated into a mechanical assembly due to its small bulk, is capable of operating at high temperatures, such as those existing in an electric motor, and capable of operating in an environment subjected to strong magnetic fields.

Through these qualities, the instrumented antifriction bearing according to the invention has worthwhile capabilities for use in a high power asynchronous electric motor, the instrumented antifriction bearing being able to fulfill both the mechanical function of a bearing and the electronic functions of detection necessary to control the motor.